Digital Map Display Wish List: a Survey of Air Force Users

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ABSTRACT

A representative sample of Air Force operational units was surveyed with regard to their mission-specific mapping, charting & geodesy (MC&G) information requirements. These data were used to identify current human factors problems associated with use of MC&G data and to document potential problems associated with the transition to digital map displays. One of the products of this survey is a wish list of digital map display features and capabilities desired by the users.

1.0 INTRODUCTION

With the changing character of warfare, information superiority is a high priority. More than ever before, coordination, synchronization and interoperability among our own forces and with our allies for coherent combined air, land and maritime force operations requires that everyone involved share a common knowledge of the battlespace. Digital map and imagery displays will play a critical role in providing a common battlespace picture.

Until the advent of digital displays, human factors work associated with MC&G products was dominated by the print medium which was highly controlled. Today, the situation has changed dramatically. The medium is now whatever display system, printer or copier the user has available. Resolution and color transfer capabilities of the medium can vary greatly. In addition, the emerging population of vector-based MC&G products will present the customer with unprecedented access to a wide variety of MC&G information displays.

The focus of this research was to identify human factors issues and problems associated with the transition from paper to digital maps. Our approach was to create a warfighter-centered knowledge engineering process focused on assuring the utility of the new products. Only by communicating directly with the warfighter, can we understand how he performs his tasks and what are his information requirements. The knowledge engineering process affords a structure for collecting and organizing the information.

2.0 METHOD

The Air Force Research Laboratory conducted a survey of warfighter units and their mission specific mapping, charting & geodesy (MC&G) product requirements for a representative sample of Air Force systems. This survey involved acquiring data on missions, aircraft capabilities, crew roles and responsibilities, and user characteristics (*e.g.* experience, age, and visual acuity). This information provided a context in which to frame MC&G specific data requirements. The MC&G-specific data collected included information requirements for mission planning, information requirements by mission segment, products used, typical environmental constraints

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under which products were used, and hardware/software system variables. These data were used to identify current human factors problems and document potential problems associated with the transition to digital map displays.

2.1 Participating Warfighter Units

Crew members and mission planners from a representative sample of Air Force systems (e.g., aircraft) acted as our subject matter experts (SMEs) for this survey. The 366th Wing at Mountain Home Air Force Base is one of only three composite wings in the Air Force, whose mission is quick response anywhere in the world. The wing includes of F-15C air to air fighters, F-15E air to ground fighters and B-1 bombers. The 552 Air Wing at Tinker Air Force Base is responsible for air surveillance and control. The 509th Bomb Wing at Whiteman Air Force Base is our first operational B-2 squadron. Our Special Operations forces were represented by both the 20th SOS with the MH-53J helicopter and the 16th SOS with the AC-130 gunship. The F-117 attack aircraft was represented by the 49th Air Wing at Holloman Air Force Base.

While the 391st was the only squadron using the Air Force Mission Support System (AFMSS) for mission planning at the time of the survey, all of the squadrons had received the AFMSS system and were waiting for training and/or certification. Therefore all were somewhat familiar with digital MC&G data.

2.2 Data Collection Procedures

The data collection procedure was based on a top-down approach, proceeding from general to specific. Figure 1 outlines the typical sequence of activities. Survey tools and methodology were developed at Air Force Research Laboratory, then subjected to field testing before actual site visits. Field testing was conducted at Rickenbacker Air National Guard Base (ANGB).
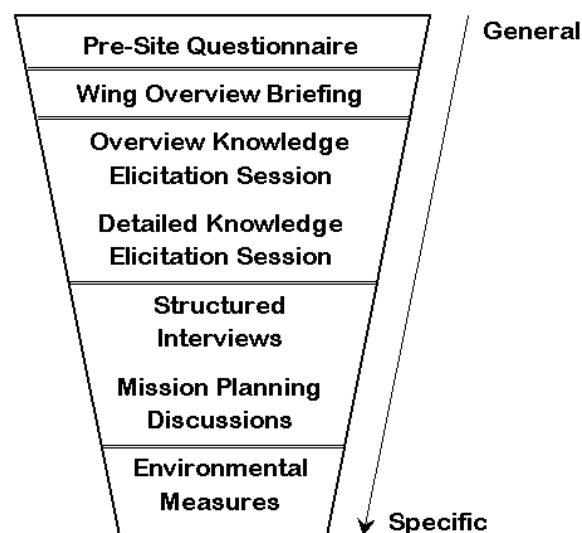

Figure 1. Top-down data collection approach.

On-site visits were conducted with all participating units. Typically, each site visit lasted three to five days depending on the number of aircraft systems, availability of key personnel and/or the expected data complexity at a particular site.

The five-member field survey team was a multidisciplinary team with each member bringing a particular expertise to the project. The team was led by a senior research psychologist with background in vision and man-machine interface. Other members of the team included a B-52 instructor radar navigator with extensive experience in using maps and charts, a human factors engineer with background in human visual performance and color electronic displays, an industrial/ organizational psychologist with background in knowledge elicitation techniques and methods, and a human factors psychologist with experience in directed survey development and feedback analysis.

On-site data collection was performed in several steps, with each step incrementally increasing the level of detail. Given the complex nature of the domain being investigated, a mix of subjective and objective data gathering tools was used. These tools included informational briefings, knowledge elicitation sessions, structured interviews, user specific questionnaires, environmental measurements, and direct observation of users performing their tasks. The procedures for the various field survey activities are described in the following paragraphs.

2.2.1 Unit Overview Briefing

Each participating organization (wing, squadron, etc.) was requested to provide a Unit Overview Briefing. The briefing was usually 20-30 minutes in duration and was typically the briefing that the unit used as their introductory briefing for visitors. Sometimes, this included a videotape of unit activities. These briefings provided starting points to generate discussion and aided in formulation of questions for the knowledge elicitation sessions. These briefings also provided a means of identifying key system functions and key personnel for participation in the knowledge elicitation sessions and structured interviews.

2.2.2 Knowledge Elicitation Sessions

Following overview briefings, knowledge elicitation sessions, using concept mapping techniques, were conducted.   Concept mapping is a knowledge elicitation technique that allows domain knowledge to be visually represented in a shared information space such as a white board. Domain knowledge is represented as a spatial network of concept-relation-concepts. Concepts, or nodes, represent key points or ideas within a particular domain while relational links between concepts denote their associations.

Concept mapping is a good technique for developing initial sketches or overviews of a particular topic domain. Figure 2 shows an excerpt of the concept map for the MH-53J. Notice that some problems with MC&G products are identified in the concept map; the JOG has color incongruencies and/or inconsistencies and there are problems with data currency on the JOG and 1:50K chart.
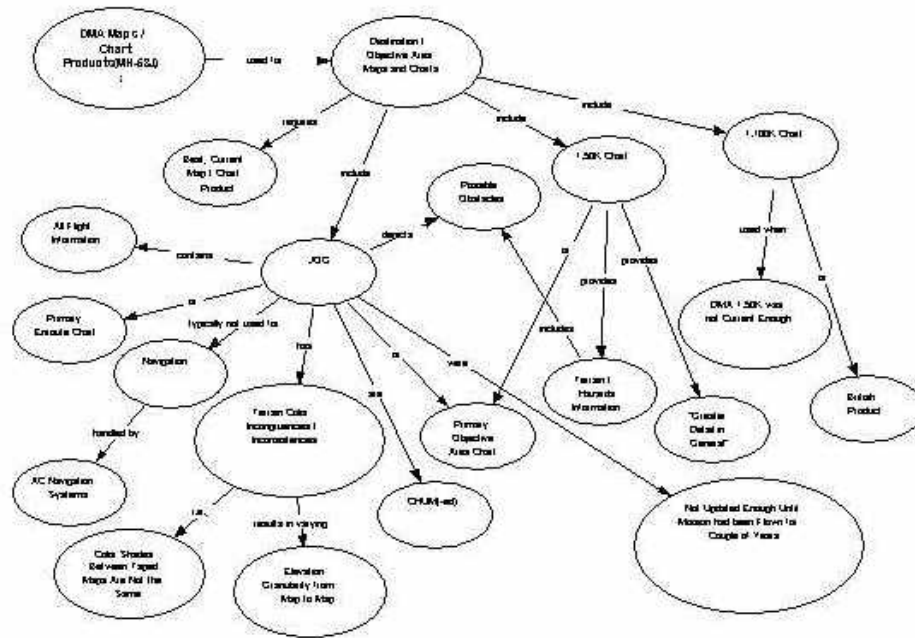
Figure 2. MH-52j Concept Map excerpt.

2.2.3 Structured Interviews

Structured interviews were conducted for each crew position and served to gather additional, more detailed information than was gathered in concept mapping sessions. Concept map information was used to select appropriate questions and tailor them to the interviewee.

Items in the question database were developed from a review of human factors issues which potentially affect MC&G product legibility and interpretability. These human factors issues were identified by performing a literature search of past and current research being conducted for aircraft systems and MC&G applications.

Questions in the database were assigned to one of five categories: User Characteristics, Mission Variables, System Variables, Environment, and Future Requirements.

The User Characteristics category permitted a characterization of the MC&G user population who participated in the survey. Included in the User sub-categories were crew position or area of specialization, training, experience, products used and visual characteristics.

The Mission Variables category was used to gain an understanding of the tasks performed by each crew position during each mission segment. Sub-categories included mission segments, information requirements, products used, and a workload assessment.

System Variables included aircraft and mission planning systems and subsystems. Sub-categories include, color-coding, symbology and text overlays, digital and paper MC&G product alterations, hardware specifications (displays, computers, copiers) and local chart printing and reproduction quality.

Environment addressed the conditions where the MC&G products were being used. This included lighting, workspace, noise and vibration.

Future requirements questions addressed planned upgrades to the aircraft and how these were expected to affect MC&G information requirements. Possible future missions were also discussed. During this segment of the interview, operators were asked what they would like in a digital map display.

Most interviews were conducted with at least two SMEs of the same crew position or specialty. The trial on-site revealed that often the interview questions generated discussion among the SMEs and resulted in more detailed information being verbalized.

2.2.4 Mission Planning Observation

In addition to the concept mapping sessions and interviews, discussions were conducted with mission planning personnel. Often many different disciplines were required to coordinate activities during the mission planning process. Mission planning is an obvious and pervasive key function in any warfighter unit; it is the intervening step between the theory and practice of the unit's mission. An active mission planning session was observed when possible.

2.2.5 Mission Segments Matrix Development

The mission segments matrix was usually built by that crewmember having the heaviest requirement for MC&G data. The SME was asked to first identify the mission segments (or phases) of an actual real-world mission. For each mission segment, the SME identified specific mission activities within the segment and MC&G products used. The SME was asked to identify the MC&G-related information requirements.

The SME was then asked to rate the importance of the MC&G products to mission success. A scale of 1-5 was used to rate product importance (1=Not Important; 5=Very Important). Finally, the SME was asked to estimate workload. This was done by designating high, medium or low for each of the three workload dimensions of Time Load, Mental Effort Load and Psychological Stress Load. A partial mission segments matrix is shown in Table 1.

2.2.6 Environmental Measures

Most aircraft have specific lighting and restrictive space environments. Ambient lighting intensity and color, and workplace design were quantified. Lighting measurements were performed using a Minolta CS-100 chromameter, a LMT B360 Illuminance meter and a LMT L1000 Luminance meter. Potential human factors issues related to the work environment were documented.

3.0 RESULTS

The raw survey data consisted of surveyors' notes; audio recordings of all concept mapping, structured interview and discussion sessions; concept maps and information sheets. There were a total of 80 survey sessions, which yielded over a thousand pages of transcribed data. A database was created from the survey data set.

Table 1. Partial Mission Segments Matrix for F-15E WSO.

Mission Segment	General Mission Planning	Target Phase Mission Planning	Pre-Flight Taxi	Take Off	Start Low Level	Target Area	Attack Phase	Fly Home
Activities =	Find safe altitudes, turn points and update points	Target phase mission planning, Target study	Route step around and INS alignment using TSD, double check of points	Take off	Start of low level, double check terrain points for descent, prepare air-to-ground radar	Prepare for target attack	Target attack	Return to base
MC&G Products Used =	**ONC**, **TPC**	**JMEMS**	20 mile **JOG**	**ONC**	**TPC** or **JOG**, **Route book**	**Imagery**	[None]	**TPC**, **FLIP**
Map / Chart Content								
Information Used =	**ONC** for general orientation, **TPC** for detailed terrain information, avoidance points, flight corridor		**Point locations**	**ONC** for big picture	**Terrain**	Exact **target location** and **identification**		**Route home**, **landing area**
Information Missing =	Minimum altitude reference points	Target images embedded in digital map		Saddle MCA not present	Minimum altitude reference points			
Unneeded Information =					Grid lines			
Better Presentation =					Better elevation lines			
Map / Chart Importance = (1= unimportant, 5= very important)	5	5	4	3	5	5	1	5
Workload								
Time Pressure =	Moderate	High	Low	Low	High	High	High	Moderate
Mental Effort =	Moderate	High	Low	Low	High	High	High	Low
Stress =	Low	Low	Low	Low	Moderate	High	High	Low

The primary benefit of the database is that it enables the researcher to extract data in a variety of ways. Several data summaries are possible such as topical data sheets, MC&G product by user matrices and mission segments analyses. Each data summary is a different approach to viewing the data. Detailed information can be found in Aleva *et al*, 1997.

3.1 Digital Map Display Wish List

A digital map display offers many benefits that are either not possible or not practical when using paper charts. These benefits include legibility in low light environments, map / chart slewing, declutter functions, zooming, and quick modifications to mission plans. In addition, printing only the portion of a map needed and customizing a map for a particular application are attractive benefits. Future digital map display benefits will continue to increase with advances in hardware and software technology.

As part of the survey, users were asked what features they would like on a digital map display. Users were encouraged not to restrict their responses to limitations imposed by current technology. This information was obtained through the structured interview and via informal discussions. Although most aircraft did not have digital map display capabilities, the aircrew and support personnel were familiar with digital map representations provided by AFMSS and/or other desktop systems. Therefore, most users were capable and willing to respond to questions about desired features.

Nearly everyone interviewed expressed an interest in having a digital map display. Of course, each user had his/her own set of specialized requirements. Often, however, the requirements were similar within each user group (pilots, navigators, mission planners, target specialists, etc.). A list of desired digital map display features is presented in Table 2. Virtually all features listed in Table 2 are available using current technology, however, many are not implemented due to hardware/software system limitations on the aircraft and desktop systems.

Users overwhelmingly agreed that a digital map display would be a great benefit in their work. Many believed it would result in reduced workload and increased situational awareness. In fact, those pilots flying aircraft that had digital map displays found this to be true.

3.2 Human Factors Issues

A number of human factors issues were identified that currently affect the usability of paper MC&G products and are expected to affect the usability of digital MC&G products as well. Few of these issues can be studied in isolation, as there are many variables that must work together and each must be adjusted to optimize the utility of the overall product.

Future concepts for aircraft crewstations and mission planning systems call for real-time imagery. This imagery supplements MC&G chart information. Proper correlation of image and chart or digital map data can potentially aid in orientation to the external environment. There are a number of human factors issues associated with how to display imagery and correlate it with a digital map display. These include matching image and map orientation and scale, whether imagery should be overlaid on terrain elevation data (if so, how many points must be matched to achieve accurate registration of terrain data and imagery), and use of symbology or text overlays on imagery.

There is a trade-off between resolution and clutter, particularly if display size is limited. Cockpits have numerous displays and controls, yet a very limited space in which to place them. Cockpit digital displays are likely to be less than 10" diagonal; perhaps as small as 4". Most desktop applications are limited to 21" displays, for financial reasons more than technological.

The displayed image often appears different from the paper original; paper charts viewed next to their digital representations generally have more detail and a larger presentation area.

Table 2. Desired Digital Map Display Features.

Feature	Description
Declutter	Selectively remove information.
Zoom	Increase resolution and size of a map area.
Slew	Move map in any direction (look ahead).
Overlay	User-defined symbols, text and colors added to a map.
Data layers	Click on a point and receive additional information (e.g., DAFIF for airfield info, TACAN lat / long and freq., etc.)
Products	Increase product (e.g., TLMs, approach plates, aimpoints, etc.)
Customize map	Ability to add information layers to a map to suit a specific application.
Map modifications	Selectively remove major map attributes (e.g., terrain on or off)
Temporal maps	Similar to Rapid Information Display, where several maps are sequentially displayed for brief periods (verify).
Scanned products	Scan in any MC&G product.
Course predictions	Predictive flight path based on aircraft heading and speed.
In-flight replanning	Modify mission plan in real-time. Critical information is displayed for new course.
Map modes	Change color scheme, symbol set, etc., in response to environment change (e.g., NVG on or off).
Real-time updates	Intelligence and other data are displayed real-time.
Better CHUM	Easier to make a single change to a digital map than to modify a paper chart. More automated.
Conversions	Coordinate, scale and datum conversions performed with button selection.
Orientation	Map is presented track-up, north-up or user-specified.
Perspective	View map from 2-D or preferably 3-D perspective (e.g., provide flight profile).
3-D immersion	Enter a virtual map (applies to mission rehearsal).

On a digital display, this issue of resolution versus clutter might be resolved through the implementation of a selective declutter function which adds or deletes certain classes of information from the chart. A zoom function that increases resolution as the operator zooms in and decreases resolution as he zooms out is another possible alternative. Yet a third alternative might be the capability to designate a chart symbol and receive additional information about that particular location (target, threat, aimpoint, terrain feature, etc.). A slew or roam capability, whereby the operator can move the display window over a chart covering a much larger area may alleviate the problem of limited display size. However, there are tradeoffs between the need for detail and the need for the "big picture" of the mission area.

Multiple datums used to develop a chart or multiple coordinate systems overlaid on a single chart are issues that should be studied further. Studies may be performed to evaluate the effectiveness of multiple datums and coordinate systems using different colors and shades (half-tone versus full-tone) as a potential solution to this issue. The issue is most applicable to paper products, although it also applies to digital raster images which are simply digitized paper maps presented on digital map displays. Further study is needed to determine the most advantageous approach to conversions between datums and coordinate systems and how this information should be displayed.

While users have individual data requirements and chart design preferences, many also expressed the desire for a common battlespace picture not only within the Air Force but also across services for joint operations. This necessitates the use of a common symbology and color coding scheme for overlay of mission information on the MC&G data. A potential symbology set, that serves the needs of all users, should be identified and tested for legibility and ease of interpretability. Likewise, color codes for MC&G product overlays should be established and tested for all current and potential ambient illumination conditions (color and intensity).

Digital displays must not only be legible but should be easily and quickly interpretable under conditions of high workload and afford the warfighter the maximum possible situation awareness. Today's warfighters are highly sophisticated and have a clear picture of what they need in a digital map display. However, research is necessary to refine and test implementation strategies in order to develop a common battlespace picture that affords the best situation awareness for all warfighters.

Differences between data manipulability based on data format may pose human factors issues. Currently, most digital MC&G displays are scanned raster images. These digital displays have only limited manipulability. Vector data format is currently under development and will provide the user with versatility to adapt a chart to meet specific information requirements. This is an attractive function to many warfighters and support personnel. Vector charts, however are relatively new products and little is known about their usability characteristics and effectiveness in comparison to traditional products.

The versatility of a digital map display, particularly using the vector format, may also create potential problems. Digital map displays allow the user to apply text, symbology and area designation overlays (e.g., intervisibility rings, restricted areas, military operating areas, etc.) onto chart data. Once overlays are applied, they may be moved, updated, or removed during a mission as needed. Several human factors issues were identified when considering these functions. Text and symbology properties such as size, orientation, arc width, color and position must be considered during design. Although text and symbology overlays may be constrained to well-defined sets and area representations constrained to fill patterns, these properties have varying perceptual qualities. Improperly designed text and symbology properties can offset potential benefits of digital map display technology.

Cockpit lighting affects the legibility of paper MC&G products. The transition to the NVG compatible cockpit with its blue-green lighting is particularly problematic for legibility of paper products whose color codes were optimized for viewing in white or red lighting. Self-luminous digital map displays are likely to create further problems of incompatibility with NVGs. A

special NVG-compatible color palette may be required. Alternatively, filters might be used on color digital displays, which could drastically change the appearance of colors.

The effects of filters for luminous displays should be tested. This is especially important when a range of colors is "removed" from the chart. As additional technologies are introduced in the cockpit that require specialized lighting, there is the possibility that digital displays will require "switchable" filters (i.e., for specific airborne devices such as NVGs or some other device that may have associated lighting compatibility requirements).

One method for attaining consistent and accurate color reproduction from paper to digital displays and output devices, or across hardware platforms, is to perform color calibration procedures. There are many different types of calibration procedures available, although some may not be applicable to users at the squadron level.

Certain fine, chart detail, such as fine contour lines and gradual color changes, will not be displayed adequately on digital devices. This lost information may or may not be critical to mission success. The level of detail required by the user must be determined to adequately define display resolution thresholds.

4.0 CONCLUSIONS

The goal of this survey was to identify human factors issues pertaining to MC&G product legibility and interpretability in Air Force applications. MC&G products are critical in providing a common battlespace picture to warfighters. Currently, the warfighter is undergoing a transition from a reliance on paper MC&G products to digital MC&G products. This transition presents unique and varied problems for the user. These may include legibility differences between a luminous map and an illuminated paper map, as well as the effects that different types of ambient illumination have upon these maps. Other problems may be associated with the ability to modify text, symbology and overlays, the versatility associated with these modifications, as well as the inherent appearance differences between a color paper product and its associated digital representation. In addition, there are problems unique to digital products, such as digitization errors, data losses associated with compression techniques and the wide variety of hardware and software being utilized at the warfighter units.

We must be aware of the emerging synthesis of National Imagery and Mapping Agency (NIMA)-supplied MC&G products with commercial geospatial information systems (GIS) and how these products differ from NIMA products. Further, we should consider the potential impact of Real-time Information in the Cockpit (RTIC). This real-time information may consist of imagery or mission planning updates from off board assets.

The issues discussed herein are not easily resolved using human factors design guides or a general knowledge of visual science. Digital map displays, particularly for the cockpit, are a relatively new technology. The vector format for data manipulation and presentation is even newer. There are a number of issues that should be studied further. Among these are the data resolution requirements of various users for both digital map data and imagery. Laboratory studies, using representative tasks, having both face and content validity, should be conducted to determine how much resolution is required to perform tasks satisfactorily. A generic task battery

should be developed which is representative of the operators' real-world tasks and which lends itself to laboratory experimentation.

The lighting issues should be studied in the laboratory where lighting can be strictly controlled. Representative workstations and the generic task battery can be utilized to evaluate vector moving map displays under the wide variety of lighting conditions which occur at the users' workstations, whether in the cockpit or in an office environment.

When the data resolution requirements have been further defined, issues of data presentation, including clutter, color coding, operator defined overlays, and commonality of displays among users can be addressed. Continued interaction with the warfighter units and a thorough understanding of their needs is critical to the success of such research.

REFERENCES

Aleva, D. L., Calhoun, C. S., Selvaraj, J. A. and Rogers-Adams, B. (1997). *Human Systems Interface Optimization of Defense Mapping Agency Products: A Warfighter Centered Approach. Phase I: User Survey.* (AL/CF-TR-1997-0080). Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH.